Students' personal work in mathematics in French business school preparatory classes

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This paper presents parts of a research study pertaining to students' personal work in the learning of mathematics at the undergraduate level. It focuses on the main results conveyed by data collected through a questionnaire completed by students enrolled in two different tracks of French business school preparatory classes, at the beginning and end of their first year of study. The approach adopted in the description and analysis of results in this paper focuses on the role of the institutional context and its impact on student work.

Keywords: Mathematics learning, student personal work, institution, CPGE.

CONTEXT

Students enrolled in preparatory classes in France (Classes Préparatoires aux Grandes Écoles referred to as CPGE) seem to achieve much better results in mathematics than those enrolled in regular universities (Castela, 2011), where student failure during the first years has long been a serious widespread problem. These specific French higher-education institutions prepare students over two academic years to enter the "Grandes Écoles", which are mainly business schools or engineering schools, by passing the "concours"[1]. In the French educational systems, the two preparatory years are equivalent to the first two years of undergraduate study at university. However, the CPGE differ from universities in many ways. They are known for their selectivity in recruiting good – if not the best – high school students who hold the French baccalaureate, as well as their supportive culture, which favours student collaboration and provides them with close follow-up by teachers, in a relatively rigid high-school-like system within stable moderate-sized classrooms. These institutions constitute a rich and interesting field of observation and study given both the resources they offer to students and the constraints they weigh on them.

Furthermore, research about student personal work is not very common in mathematics education, in France and elsewhere. There have been few studies in mathematics didactics that tackled this topic however mostly in a marginal manner. In addition, given the diversity of the situations in higher education in France, the number of studies relevant to each situation is very limited. Some studies in sociology and education have closely explored student personal work but without taking into account disciplinary specificities. Our work comes as a continuation of the research conducted by Castela (2004, 2009, 2011) who studied students' personal work in mathematics in high school (grade 11) and in higher education (comparing university and CPGE). Our study focuses on the personal work of students enrolled in two different tracks of business school preparatory classes, Scientific and Technological[2], during their first year of study. S track students hold a scientific baccalaureate and have a strong background in mathematics and sciences; whereas T students have had a teaching specialized in human resources, marketing, business and finance or information systems with little focus on mathematics[3]. Hence, our study adds to the existing research about CPGE by targeting an unprecedented population while emphasizing the diversity brought by the two tracks. Furthermore, our study explores specific aspects of the "enveloping" institutional func-

1 The "concours" are national competitive exams which students take by the end of the second preparatory year in order to enrol in the "Grandes Écoles". There are specific required written and oral exams for each type of school.

2 In what follows, we will designate the tracks by the letters S and T respectively.

3 The background difference is clearly reflected through the mathematics level of students in each track.

tioning of the CPGE analysed and evidenced through a sociological study (Darmon, 2013) from a transversal point of view, adding a disciplinary focus on mathematics, while examining the link between the personal organization and the institutional organization of study in CPGE. It also introduces methodological novelties to the existing studies about CPGE in terms of data collection, by combining quantitative methods with methods that give a closer access to students and teachers.

CONCEPTUAL FRAMEWORK

We borrow several constructs from French didactics of mathematics and sociology in order to build our conceptual framework. In what follows, we define the two main components of this framework which are addressed in this paper.

Firstly, the notion of institution is at the heart of this research. We use the definition of an institution given by Chevallard (2003) as our starting point. He describes an institution as a social system which allows and imposes on its subjects – that is people who occupy different positions within the institution – ways of doing and of thinking. In the broader sense of the term, we consider that the institution designates the CPGE. We adopt Darmon's perspective who describes the preparatory institution as an "enveloping" institution,

> ...powerful but not totalitarian, violent but concerned about the well-being of its members, it operates by individualizing to the extreme rather than homogenising, thus reinforcing its take over the individuals which are its members (2013, p. 28).

The other essential notion we consider is student personal work. We conducted an extensive review of literature about student personal work, in order to define the aspects we are concerned with in our study, and situate them with respect to other research tackling the same topic. We advocate that, in mathematics, students need to construct practical know-how in addition to the theoretical knowledge they acquire in order to solve mathematical problems. We refer to Castela's work (2011) on mathematical functioning and her contribution to the praxeological model. Our underlying hypothesis is that such practical knowledge is not explicitly taught nor institutionalized. Thus, students are required to engage in "autodidactical" personal work in order to extend and complete what has been initiated in the classroom. In our study, we are looking to define the nature of this autonomous study and the gestures involved in it, that is what students do in addition to solving problems in order to learn something in mathematics. On one hand, we focus on the disciplinary specificities of mathematics in student personal work. On the other hand, we perceive personal work as defined and influence by the institution and not as an isolated individual endeavour.

RESEARCH DESIGN

Our target group includes first year students who come from preparatory classes in three different Parisian schools[4] of both tracks, where three volunteer mathematics teachers have accepted to cooperate for the research and allowed us into their classrooms over two consecutive academic years (2011–2012 and 2012–12013).

The study uses a combination of qualitative and quantitative methods in order to answer the research questions; the following questions are at least partially addressed within the scope of this paper:

- How does students' personal work evolve throughout a preparatory year, in terms of quantity and forms of study?
- What are the forms of study that students exhibit on their own initiative, in addition to those prescribed and supervised by teachers?
- What forms of study are exhibited by "good" students as opposed to those who are "weak"?
- How do social relationships promote student work, in particular the relationships that are established between the students and those built with the teachers?

Several instruments have been used to collect data: informal discussions with students and teachers, email exchanges with few volunteer students, samples of student notes and documents, student questionnaires,

4 Given that it is not possible to disclose the school names, we refer to them by their initials: D and K from the S track, B from the T track.

teacher questionnaires, interviews with few students, and interviews with the three teachers. All data collected through qualitative methods is intended to provide explanatory elements and validation for the hypotheses and conclusions brought to light through the student questionnaire, which is the main tool of our study and the focus of this paper.

Through this questionnaire, we seek to identify ways of working which are common to students in general, as well as those that differentiate the "good" students from the "weak" ones. We determine a student's achievement level (good, average or weak) solely according to his/her end of year mathematics grade. In fact, the grade is the only criterion used in the "concours" to evaluate students' success and rank them for admission to the "Grandes Écoles". We also look to establish comparisons between the schools and/or the tracks, and examine how the ways of studying evolve throughout the first preparatory year, while considering the influence of the particular institutional context of the CPGE and the social relationships on students' work.

This pre/post questionnaire explores the ways students work for the mathematics course at two moments of their educational path, at the end of grade 12 and at the end of the first preparatory year. It was inspired from several previous similar questionnaires used in studies related to our topic (Adangnikou, 2007; Castela, 2004; Najar, 2010) and was designed to match our research goals and conceptual framework. It includes 55 items from five categories: general work habits (including problems encountered by the students), in class (following, taking notes), between two sessions (studying the lesson, solving exercises, making summary sheets, preparing the "colles"[5]), when reviewing before an exam (the resources, the way of working, the exercises), and self-evaluation of performance and results. The two versions of the questionnaire (pre/post) are almost identical in terms of the questions asked, but each focuses on a different moment of the student path. Most of the items are four-level Likert items (the ordered responses are "never", "sometimes", "often" , "always", or equivalent statements for few specific items), in addition to two multiple choice items, five yes/no answer items, and two open-ended questions (the latter are only found in the post version of the questionnaire since they pertain to the "colles"). The questionnaire was filled out by students of the three schools involved in our study, respectively at the beginning and at the end of the first preparatory year, over two consecutive academic years (82 students, then 97 students).

We used SPSS in order to conduct descriptive statistics analysis and hypothesis testing for the data gathered through student responses. For each item and for both moments of the study, the frequencies of responses were first calculated for the whole sample, then for subgroups of students created according to school (B, D or K), track (S or T) and level of students (good, average, weak) respectively. McNemar tests were used to verify the significance of the evolution of frequencies between the beginning and end of year for both academic years. Chi-square tests were used to check dependence relations between each item responses and the different subgroup modalities. Next, the items were crossed two-by-two in order to look for significant dependence relations using Chi-square tests.

FINDINGS

In this section, we present some of the main findings of the questionnaire data analysis which was structured around eight themes: 1. collaboration between the students, 2. student difficulties, 3. taking notes, 4. managing work and revisions, 5.between two sessions, 6. resources, 7. before an exam, 8. colles[6]. We give few examples of items that differentiate between the two tracks on one hand and between the good and weak students on the other hand.

5 A "colle" is an evaluation tool specific to preparatory classes. It classically takes the form of a one-hour oral examination by groups of three students working individually but simultaneously on the classroom board, answering lesson questions and/or solving problems given by the teacher who is present to supervise and grade the work. In mathematics, a student is subjected to a "colle" every two to three weeks. The conditions and functioning of a "colle" may vary from one school to another. The questions related to the "colles" (4 Likert items and 2 open-ended questions) are only found in the end of preparatory year questionnaire given that this tool is not used in grade 12.

6 Given the specificity of the "colles" to the CPGE context, it is difficult to fully understand their characteristics without a detailed description. Hence, we omit the results pertaining to this theme given the space limitations of this paper.

Collaboration between the students

The data analysis shows that collaboration with classmates is highly valued by students of preparatory classes, even though it doesn't always take the form of group-work. Group-work seems to be a relatively common practice, with an average proportion of students who report working in groups often or always around 50%. The other half – students who never or only sometimes work in groups – can be at least partly accounted for by the fact that students in preparatory schools come from different areas outside Paris, hence they do not live close to school and choose to work most often at home rather than in school or at a classmate's. In addition, group-work is more widespread among students of the S track on one hand, and among the good and average rather than the weak students of both tracks on the other hand. Collaboration also takes the form of a solidarity bond between students who seem to rely on each other for moral support and encouragement for non-academic purposes. In fact, more than 80% of the students totally agree with the fact that mutual support between classmates is as determining as one's personal work for success. This disproves common stereotypes which advertise harsh competition in preparatory classes. In fact, teachers encourage student collaboration by allowing it in their classrooms for specific purposes. Irrespective of the form it takes, we believe that collaboration between classmates has a positive impact on students' personal work.

Student difficulties

Many students in preparatory classes have time management and concentration difficulties when studying at home. The proportions of students who say they often or always have difficulties by the end of the preparatory year are higher than those of grade 12, exceeding 60% in several cases. This is not surprising given the demanding requirements of these classes and the long intense school days. Many students also find it hard to stay focused and follow in class, the lesson rhythm being too fast for them. This problem is more frequent among students of the T track, particularly the weak ones, for whom the situation is aggravated compared to grade 12, whereas students of the S track seem to become less distracted by the end of the first preparatory year. One hypothesis which can partly explain these different behaviours is related to how students of each track perceive the importance of mathematics. This derives from the fact that mathematics is the main subject in the S track and plays a crucial role in the "concours" and recruitment process, while it can be counterbalanced by other subjects in the T track. Despite the many problems they face, students seek less help from others (teacher, parents, friends...) than they used to in grade 12. In fact, the number of students who solicit the teacher's help when they don't understand something in class radically drops by the end of the first preparatory year. This practice remains more common among the good students. Likewise, although the number of those who get help from others such as parents or friends varies from one class to another, the average proportion does not exceed 50%, which shows that students tend to handle their difficulties on their own. This can be interpreted as a statement of independence or a lack of confidence in others. Some students, mostly weak ones, seem to completely shut themselves off from any external assistance, including discussions with classmates, which could suggest they have given up on mathematics.

Taking notes

We explored the way students take notes during the lesson and what they add to those notes. More than 90% of the S track students copy everything the teacher writes on the board, while the proportion drops to around 73% for those of the T track. On the other hand, fewer students take notes based on the teacher's oral comments. The proportion of those who do differs from one class to another, but it doesn't exceed 60%. This seems to be related to the students' level in mathematics and their difficulties while following the course pace. As for student contributions to the notes, many claim that they add personal comments and signs, especially good students, but very few indicate the things they did not understand while taking notes. These behaviours are analyzed and interpreted in light of the differences between the teachers' lessons, the content of the sheets they distribute to the students, the ratio of written and oral comments they add, as well as the students' level and difficulties.

Managing work and revisions

We tried to establish patterns in the way students organize and schedule their regular work and exam[7]

7 In CPGE, mathematics exams are not typical university exams, but are rather similar to high school exams in format and content. They take place regularly every four to five weeks on a Saturday, are usually four hours long, and consist of exercises related to the last chapter or two chapters covered in class.

revisions for the mathematics course. Despite the differences between classes, it is possible to observe that, compared to grade 12, more students use a tentative work plan to organize their work. It appears that this practice is more common among good students of the T track. Additionally, the number of students who wait for exam periods to review their lessons and work decreases by the end of the first preparatory year, particularly in the S track, where many students become more systematic in their work. This can be partly attributed to the "colles" which require students to learn their lesson fortnightly. Similarly, very few students start exam revisions at the last minute or the day before the exam, while more students begin their revisions two days prior to or at least one week before the exam. This shows that students in general become more organized, regular and anticipatory than in grade 12, although some differences and exceptions can be noted. We can also find extreme cases of both very studious students and very careless students. No statistically significant conclusion can be drawn about the differences between good and weak students with respect to ordinary study habits or exam revisions.

Between two sessions

We first consider what students do with the lessons covered in class by focusing on the main three actions of mathematics learning: read, understand, and learn. Between two mathematics sessions, around 35% of the students on average read everything that has been done in class, while almost 45% of the students go over the things they didn't understand in class, a practice mostly common among good students. In addition, less than half the students learn the lesson (theorems, definition, formulas, proofs). These numbers lead us to believe that only some students work on a regular basis between sessions, probably in order to be prepared for the "colles", while others tend to keep most of the work for exam revisions. As for the exercises, few students in schools B and D (around 28% on average) solve the exercises assigned by the teacher for the next session, as opposed to more than 60% of the students of school K. Likewise, very few students in schools B and D complete the exercises which the teacher didn't finish in class, while this seems to be more common in school K. These results begin to reveal a particular attitude among the students of school K with respect to exercises, which is confirmed through the analysis of further items.

Resources

Next we consider the resources which the students have at their disposal in order to prepare for exams. First, we examine summary sheets, self-produced resources that students create using lesson notes and/or exercises. Around 40% of students create summary sheets, mostly by selecting and copying important elements from the lesson and to a lesser extent from exercises. As for the resources provided by the teacher, most students (more than 80%) say they are satisfied with the lesson which they find complete and sufficient for them to succeed, except for those of school D in 2011–2012 where the rate is 40%. Furthermore, around 60% of the students of schools B and K study the comments written by their teacher on their previous exams or graded homework, as opposed to only 45% of those of school D. Finally, less than half the students of schools B and K use resources other than their teacher's lesson, such as books or online references, as opposed to more than 70% at school D. In fact teachers discourage such practice. These numbers, in particular those of the class of 2011–2012 at school D[8], strongly suggest that special consideration should be given to the teacher role while interpreting the data.

Before an exam

In this section, we explore the way students review for an exam. To start with, we analyze the way students study the lesson. It comes as no surprise that students give high importance to learning formulas and their application conditions by heart, and to a lesser extent to learning definitions and theorems. In fact, between 65% and 80% of students verify that they know by heart the different lesson components when preparing for an exam. This could compensate for the fact that more than half the students do not learn their lesson between two mathematics sessions as said above. These practices are slightly more common among students of the S track on one hand and among good students on the other hand. Moreover, 60% of students of the T track on average read and try to un-

8 In this school, two different teachers taught mathematics over the two years of our study. A detailed analysis of several items pertaining to the teacher role as well as information gathered from the interviews and discussions with students and teachers indicate that the relationship between the first teacher (class of 2011–2012) and the students was problematic, while things were smoother for the new teacher despite some minor issues. Being aware of this delicate situation allows us to explain some of the numbers we see, such as the lack of appreciation of the first teacher's lesson.

derstand proofs, and 40% try to re-do proofs as part of exam preparations, while the respective average proportions for students of the S track are 50% and 15%. Hence, it seems that proofs play an important role in the T track exams, whereas the S students encounter them mostly in the "colles". Despite these differences, good students in general and in the T track in particular seem to pay more attention than others to studying proofs before exams. Lastly, 75% of students of the S track declare that they try to extract ideas (examples, methods, tricks) to remember when studying before and exam, while only 45% of students of the T track do so. These numbers underline differences between the two tracks which can be partly attributed to the nature and content of exams for each track. In fact, the latter are aligned with the "concours" objectives and requirements which are not the same for both tracks.

Lastly, we consider the way students handle solving exercises before an exam. To the multiple-choice question "the most important thing to do in order to succeed in mathematics when solving exercises", we provided four suggestions: 1. "being able to solve the exercises assigned by the teacher", 2. "practicing by solving other problems than the ones assigned by the teacher", 3. "identifying standard problems and knowing the methods and tricks to solve them", 4. "other (to be specified)". The majority of S students chose the third option, while the most common choice for T students was the first option. This difference between students of the two tracks can be interpreted using Castela's (2004) work styles conceptions: the choice of T students matches the "reproduction conception", which is also that of successful university students, while the style of S students tallies more with the "transfer conception", given that they tend to look for tricks and methods which can be applied to other problems. Another main difference between students of both tracks is relevant to the way they handle exercises that had been previously solved in class. It appears that, on average, twice as many T students as S students say they only read the correction of an exercise and try to understand it, instead of actually trying to redo the exercise either mentally or by writing. Furthermore, weak students of both tracks tend to avoid redoing the exercises by writing, and settle for either solving mentally or reading the correction, but no such general observation can be made regarding good students. We can conjecture that while redoing exercises by writing is necessary in some cases, it is not always obligatory. However, in order to get something out of these previously solved exercises, it is inevitable to redo them at least mentally, since mere reading does not seem to contribute towards success in mathematics. The difference between the two tracks is also underlined by the fact that more S students solve exercises of different types than T students. For example, 80% of S students on average solve exercises similar to the ones that are most likely to be given in exams, while less than 65% of T students report doing so. Similarly, solving exercises which have not been prepared prior to exam revisions is a common practice for 65% of the S students as opposed to less than 40% of the T students. It is important to note that we also find differences within the S track between the students of schools D and K, and between the two classes of each school. Hence, it is hard to formulate comparisons between students of different levels. Yet we can summarize the main commonalities as follows: it seems that good students are more selective with respect to the type of exercises they choose to work on before an exam; they tend to tackle the long and difficult ones rather than the simple ones or those they previously managed to solve.

DISCUSSION AND CONCLUDING REMARKS

Through our approach, we first consider the CPGE institution as a whole, and then we focus on the functioning of each classroom considered as an institution on its own in order to interpret the results. We examine each classroom as an institution whose stability allows the transmission of norms (Monfort, 2000), despite the different students and in some cases different teachers over the years. Moreover, through its dual role of subjugating its members while providing them with the necessary resources, the institution is responsible for transforming and producing particular student aptitudes. Thus, we investigate the causes behind the observed phenomena at the level of the institution rather than the individual.

It is very difficult to sum up our results given the extensive data and the different levels of analysis involved in the study. In fact, what we present in this paper are only some of the main findings which are accessible to the reader who is not exposed to all the details of the work. For example, we have omitted most of the results of items that distinguish between the three different schools and/or the two years of study. In addition, some items do not suggest any consistent

behaviour across schools, classes or years, but instead either produce non-results or reflect special cases.

Nevertheless, we can formulate three main conclusions which are repeatedly conveyed by the results of several items. The first one pertains to the class of school B in 2012–2013. Students of this class appear to be much less studious and less diligent than those of the other classes, in particular when compared to their predecessors of the class of school B in 2011–2012. In fact, their responses suggest that they work significantly less than the others in general as well as before exams. The second conclusion pertains to the class of school D in 2011–2012 which seems to be facing a problematic situation with the teacher. Some repercussions of this situation are still visible in 2012–2013 despite the change of teacher, but to a lesser extent. The third conclusion concerns the class of school K in 2012–2013. Students of this class seem to share some common study gestures which differ from those of other classes, in particular those of the S track, especially with regard to exercises. This is partially ascribed to the fact that two-thirds of its students have an average level in mathematics by the end of the year, as opposed to other classes where more than half the students are weak.

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